TECHNOLOGICAL CHANGE AND INNOVATION
IN A
NETWORKED ECONOMY

Paper prepared for the Eindhoven Centre for Innovation Studies (ECIS)

Dr. ing. H.W.J. Donkers
IMAG-Wageningen UR

16 August 2001
TECHNOLOGICAL CHANGE AND INNOVATION IN A NETWORKED ECONOMY

Harry W.J. Donkers

Keywords: technological change, innovation, learning chains, networks, technology assessment

1. Introduction

In the models of standard economics, innovations appear as extraordinary events, coming from the outside, which temporarily disturb the general equilibrium. After a process of adjustments, reflecting the work of the price mechanism, a new state of equilibrium is established. This might have been adequate in pre-industrial societies, in modern societies, however, interactive and innovative capabilities are fundamental in order to hold competitiveness.

The focus of this paper is on recognizing that technological change is in our open globalized societies a complex dynamic process that involves many social and economic factors and a wide variety of individuals, institutions and firms, co-operating in different chains and networks. Various models of technological change and innovation are reviewed, see Table 1 for a summary. The capacity of an economy to derive competitive advantages from technological change and innovation is in the end dependent on the dynamic interactivity with which the networks are involved in developing, diffusing and applying information and knowledge.

Soete and Ter Weel (1999) point to the importance of the technical as well as the social integration of technological change: both within firms as well as within chains and networks and within society at large. In the knowledge based economy this is recognized as the importance of interactivity between technological progress and the social and economic factors involved. These form the conditions for creating successful innovations.

Innovation is a ubiquitous phenomenon in the modern economy. In practically all parts of the economy, and at all times, there are on-going processes of learning, searching and exploring, which result in new products, new techniques, new forms of organisation, like chains and networks, and new markets. Thus: innovation is a fundamental capability of firms, networks and societies in order to hold their ground. From this perspective the current debate on the networked economy will have to recognize to a much larger extent the new structural features of innovation.

1 IMAG-Wageningen UR
2. Techno-economic paradigms

The relationship between society and technology is analysed in the past from various viewpoints. Is technology influencing society or vice versa? There are two extremes. On the one hand we have the ‘technological determinism’. By this principle technology is developing according to its own internal necessity and out of dynamics beyond human control. This approach focuses on the impact of technology which is seen as the distinguishing element between the past and the future, Toffler (1980), Glider (1989) en Smith and Marx (1994). On the other hand there is the ‘social determinism’. The Social Construction Of Technology (SCOT) points to technology as being through and through social, Pinch (1996).

Social progress and well-being is often seen as the result of technological change. Inherent to technological development are possible negative effects. Technological development always bring forward societal chances as well as risks (e.g. pollution of the environment) and can even dominate human being and (after Hiroshima) threaten mankind. The direction of technological development receives continuously interest. One of the ideas, which go back to the philosophy of Bacons rationalism in the 17th century, is that possible negative consequences are always solved by more technology.

The concept of technological change and innovation as the main engine for economic growth, was already stressed and at the core of economic thinking from the late eighteenth century on. Classical economists, such as Karl Marx and Joseph Schumpeter, gave a dominant role to technological progress. The innovative potential of technical systems was not always seen as unlimited. In Marx’ approach we see his hypothesis of a decreasing profit rate that in the end will stop economic growth. Schumpeter observes continually new basic technologies coming into existence, that carry a period of strong economic growth, thus forming a sequence of techno-economic paradigms. E.g. the boom in the 19th century resulted from the steam-engine and of the availability of cheap transport. In this line ICT can be seen as the motor of the boom of the end of the 20th century. Will nanotechnology create another boom in the 21st century?

Economists have always been aware of the crucial importance of technological change and innovation for long-term-economic growth. Until a decennium ago in most cases however technological change was treated as an exogenous factor, that means new technologies came, as manna, from heaven. The development could not be influenced, technology was a black box, that could only be opened by technicians. The implicit idea in the orthodox economics view of exogenous technology, that can be used by either firm if there is access to the relevant information, is yet not only rejected but replaced by the fundamental question about what determines the kinds of technological capabilities firms get under control and how these capabilities do evolve over time.

The perception of the nature of innovation processes has changed significantly over the last decade. It is not any more the development of the ability to discover complete new technological principles but the ability to exploit systematically the effects produced by new combinations and use of pieces in existing stock of knowledge. Yet there is little doubt that the way to use a particular technology is fully part of that technology. Human skills are essential complementary assets to implement, maintain, adapt and use new physically embodied technologies. From this perspective human capital and technology are two faces of the same coin, two non-separable aspects of knowledge accumulation.
3. ‘Learning’ process

Growth in the proportion of GDP accounted for by the high tech industries, growth of knowledge intensive services such as education, communications or information, of investments in information and communication technology, etc. has brought OECD (1996) to widely raise the idea of a ‘knowledge-based economy’. Knowledge should be understood in a broad notion. Knowledge accumulation include technological change, which not only encompass R&D, but the whole spectrum of scientific and technological activities from invention, to diffusion, from basic research to technological mastery. There are features of the renewed importance given to knowledge for economic growth and welfare, Soete and Ter Weel (1999). The consensus on the importance of knowledge for industrial competitiveness is closely related to the emergence of ICT, which have resulted in a dramatic decline in the price of information processing. ICT makes codified knowledge, data and information much more accessible than before to all sectors and agents in the economy.

Innovation is a gradual and cumulative phenomenon, i.e. this gives rise to the hypothesis that innovation is path dependent: future innovations depend on the past. An innovation may thus be regarded as a new use of existing possibilities and components. In Schumpeter’s terminology innovations and ‘new combinations’ are synonyms. This means that there is no reason for distinguishing between technology development and technology use. The character of innovation however might be very different: from easy to find and to realise new combinations, taking an enormous intellectual effort or an extremely creative mind to identify a potential new combination until radical breaks with the past, making a substantial part of accumulated knowledge obsolete. It is well-known that Schumpeter held two different approaches of the innovation process. Nelson and Winter (1982) model Schumpeterian technological regimes, representing two extreme theoretical cases of technology accumulation. Schumpeter Mark I is characterized by the key role played by new firms in innovative activities, i.e. creative destruction. The model is characterized by low appropriability and cumulativeness, and that the knowledge is mainly (firm) specific, codified and simple. In such a perspective the distinction between invention, innovation, and diffusion as separate stages becomes blurred. An innovation does not stay the same throughout its diffusion. Thus: innovation appears not as a single event, but rather as a continues process. Schumpeter Mark II the key role is fulfilled by the large and established firms, i.e. creative accumulation. This model is characterized by high levels of patenting and hence creates monopoly rents in the intermediate goods sector. This high level of appropriability leads to less spillovers as compared with the Mark I model, reinforcing the tacitness of knowledge.

The idea of ‘systems of innovation’ (Freeman, 1987) has a fifteen year history. Lundvall (1992) gives the broadest definition of a ‘national system of innovation’ which includes: all parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring – the production system, the marketing system and the system of finance present themselves as subsystems in which learning takes place. The core of a system of innovation is made of co-operation across those organizations and institutions regulating the creation, diffusion and use of knowledge and technology. A continuous process of innovation is now a prerequisite of survival for companies which implies interactive learning at every level both inside and outside the firm (Lundvall and Johnson, 1992).

Though there are some differences knowledge accumulation can be analysed like the accumulation of any other capital good. One can apply economic principles to the production and exchange of knowledge. Knowledge is intrinsically endogenous to the economic and
social system and is not an external black box factor. Scientific activities and technical change are becoming increasingly interdependent activities. Not only science and R&D efforts (explicit knowledge) are meant here, but also learning takes place in connection with routine activities in production, distribution and consumption (tacit knowledge) and produces important inputs to the process of innovation. Such activities include learning-by-doing, increasing the efficiency of production operations (Arrow, 1962), learning-by-using, increasing the efficiency of the use of complex systems (Rosenberg, 1982), and learning-by-interacting, involving users and producers in an interaction resulting in product innovations (Lundvall, 1992) Thus innovation is a learning process that is rooted in systems of production in the prevailing economic structure. This formed an important element in changing our visions of society and innovation. Caracostas and Muldur (1997) put it as follows: ‘Society is now a ‘learning’ society, growth renders the process of technological change and intangible factors endogenous, and the development is now partly driven by perceived needs’. Technology is like a recipe: who works with the recipe makes a difference.

4. Social shaping of technology

A few decennia ago various attempts were undertaken to open the black box of technological change and study endogenous technological change and innovation. Technological development was made endogenous, Romer (1993), Rosenberg (1994), Van Meijl (1995), Aghion and Howitt (1998). Neo-classical economists who believe in ‘endogenous growth’ have shown that sustained growth depends in the longer term on the accumulation of four main factors: physical capital, technology, human capital and public capital. The embodiment of technology not only refers to physical capital, as long has been recognized, but also to embodiment of technology in people (Schultz, 1961).

It is generally recognized that interaction between individuals, firms and institutions constitute an important factor in the process of technological innovation. Within sociology also important trends dealing with technological change can be identified. Williams and Edge (1996) argue that technological change at the end is determined by social factors, as the way potential users see a specific technological change and the way power is distributed among groups of stakeholders in such a change. Also Pinch and Bijker (1987), Callon (1994) and Latour (1988) pointed to the highly social nature of science and technology. Caracostas and Muldur (1997) define this ‘social shaping of technology’ notion as follows: it explores the social processes related to technical change; negotiation between different social groups and actors as a focal point, emphasizing concepts like flexible interpretation of technology and technological controversy; it highlights the choices between different technical options potentially available at every stage in the generation and implementation of new technologies.

Thoughts within social constructivism state that above all things social actors weigh chances and risks of technological development, and shape technological development (SCOT).

5. Integration in chains and networks

In his early work on the theory of economic development Schumpeter pointed to entrepreneurs, who act individually as the most important as the most important economic agents bringing innovations into the economic system (Schumpeter, 1934). Later he revised his theoretical scheme, however, by giving a critical role in the collective work in R&D
laboratories (Schumpeter, 1942). One of the most important institutional innovations in the last century was the establishment of R&D laboratories in the big private firms (Freeman, 1982). Interactive learning and collective entrepreneurship are fundamental to the process of innovation. To pursue this trajectory further the innovation process is developing from firms to co-operation in chains and networks. Chains and networks are formed for the purpose of value creation. Physical, information and socio-economic objects are transformed in a value creating process, see Figure 1. Within a network users and producers who belong to different subsystems might get involved in interaction. It is important to realise that the behaviour of agents belonging to different (sub)systems is governed by different rules and norms. Also assumptions regarding the rationality of agents affects the process of innovation.

To understand the innovation process in a networked economy we need a stratification of the universe. The behaviour of individual firms is embedded in a social environment. North (1990) distinguishes between the institutional environment and the institutional arrangements which play within this environment. At the level of the institutional arrangements chains and networks are active, working together in the value creating process. The institutional set-up is an important dimension of the system of innovation. At the operational level (micro) the actual production, distribution, and consumption activities take place, with accompanying material, financial, information and knowledge flows. Firms are cooperation in networks and form institutional arrangements (meso). These arrangements relate to the technological trajectories and paradigms focusing the innovative activities of scientists, engineers and technicians. This meso-level is a fly-wheel for renewals.

**Figure 1. Model of Knowledge Domains of Chain and Network Studies**

<table>
<thead>
<tr>
<th>Value objects</th>
<th>Chains and Networks</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical objects</strong></td>
<td>Physical assets</td>
<td>Technogram</td>
</tr>
<tr>
<td></td>
<td>Resources, products and services</td>
<td></td>
</tr>
<tr>
<td><strong>Information objects</strong></td>
<td>Information (data and messages)</td>
<td>Infogram</td>
</tr>
<tr>
<td><strong>Socio-economic objects</strong></td>
<td>Human Resources and knowledge Financial Capital</td>
<td>Sociogram</td>
</tr>
</tbody>
</table>

The networks are embedded in an institutional environment (macro). In a world characterised by innovative activities uncertainty will be an important aspect of economic life. The institutional environment make it possible for economic systems to survive and act in an uncertain world. A characteristic of the institutional environment is their relative stability over time. The institutional environment on the one hand provide the stability needed for innovative efforts to take place and to be successful, on the other hand innovation need flexible structures to be effective.

Technological and societal integration of technological development is an important argument for co-operation in chains and networks. Apart from active players in the chain involved with
production, distribution, etc. also actors from government and societal groups take part. The participation of these groups is of two kinds. In the first place these groups participate in the steering of the integration process towards societal desired systems exploiting positive externalities. In the second place these groups contribute towards sustainability by e.g. avoiding environmental hazards (minimising negative externalities). Without this kind of participation a gap would exist between technological possibilities and the social constraints of sustainability. To make this contribution effective an innovation trajec must be followed. Also ‘back-casting’ is a technique that can be used

Within social constructivism ‘Actor-Network Theory’ sees people and things (technology) as equivalent actors in networks that aim at commun goals (Latour, 1987 en Callon, 1998). Actors are ‘entities that do things’, Latour (1992). An actor-network is not restricted to ‘social actors’. A network ties together two systems of alliances: people (everyone who is involved in the invention, construction, distribution, and usage of an artifact), and things (all the pieces that were already on stage or had to be brought into place in order to connect the people). Describing these respective systems leads to a ‘sociogram’ and a ‘technogram’ (see Figure 1) (Wasserman en Faust, 1994). A case study applied to the GIS system is given in Martin (http://weber.u.washington.edu).

Related sciences that pay attention to networks in relation to technical change and innovation are in sociology: the Parsonian Systems Theory revived and revised as ‘neofunctionalism, Colomy (1992), Castells (1996); in economics new concepts of path-dependence and increasing returns have found acceptance, Arthur (1994, 1996); economists payed also attention to evolutionary models with path dependency and learning as technology influencing factors, Nelson and Winter (1982). Dosi (1982) and Rosenberg (1994); from natural sciences and biology the field of complexity has been opened and developed, Mitchell (1992), Coveney and Hghfield (1995).

With Soete and Ter Weel (1999) we conclude that the whole spectrum of scientific and technological activities - from invention to diffusion, from basic research to technological mastery - for product design, production and delivery is closely related to the organisational architecture of productive networks and their value adding processes.

In the operational field technological development can not be seen apart from labour and organisation. Jolink and Vromen (2000) are talking of a ‘triad’, i.e. a certain configuration of labour, technology and organisation that all together form a dynamic and interdependent entity. The behaviour of individual companies takes place in a societal environment. North (1990) distinguishes between the institutional environment and the institutional arrangements. At the level of the institutional arrangements networks are active in the process of adding value. These networks are continuously in interaction with the environment.

6. Innovative technology assessment

Technology Assessment (TA) originated in the early seventies as an attempt to manage technological developments in a societal context. TA investigated possible consequences (economic, social, cultural and ecological) of new technologies. Smits and Leyten (1991) showed that this method dit not provide good results. The ‘Constructive Technology Assessment’ (CTA) tried to get used to this by organising also the discussions about those possible consequences. The practical consequences are, according to Van den Besselaar
(1998), not yet promising because the systematic character of the technological development is underestimated. The CTA method therefore runs behind the facts. A gap exist between the technological possibilities and the societal desirabilities or societal requirements. What is necessary is an interaction between both disciplines. Already Grin et al. (1997) observed this finding. These authors suggest an Interactive TA. A characteristic of this relatively new type of TA is that it takes into account the viewpoints of all the interested parties. It strives towards a synthesis of ‘stakeholders’ and ‘players’. Synthesis, however, is not always possible and even not always the best thing to do. Moreover, synthesis is not a goal in itself. It is better to look for creative innovations during TA. Actors must think beyond existing frameworks and this innovative approach may lead to essential new development trajectories. Interactivity is a necessary condition for this but not a sufficient one. To bridge this gap an innovative approach is necessary that provides creative and perhaps unexpected solutions. Only in that case technological development will be in accordance with societal requirements. A development will become possible that administer justice to the real potential of technological possibilities and societal desirabilities. We name this Technology Assessment trajectory that centres on this innovative interaction ‘Innovative TA’. Starting point of Innovative TA is closely related to the core of both the evolutionary economics and the new institutional economics. Evolutionary economics sees technological development as a dynamic process (Nelson and Winters, 1982), while new institutional economics focuses on this process where a lot of actors and factors play a role, and where much dependencies exist between the different technological trajectories, companies, sectors and their environments (North, 1990).

The consequences of social requirements with regard to the technology and the desired technological development itself are two distinct features. The relationship between both must be made explicit and has to be managed. ‘Innovation management’ helps in creating ‘innovative networks’ or ‘clusters’, providing maximum chances for innovation (creative sessions, brainstorming, unexpected encounters, lateral thinking). Innovative TA organises this innovative interaction according to the principle of ‘society controlled technology development’. According to this principle the starting point is related to the possibilities of the market (desirability). The technological possibilities come in the second place (feasibility), taking into account at the same time the organisational aspects, logistics and efficiency (effectiveness) (W.M.F. Jongen, 1997). In fact Innovative TA is organising an integration between social sciences and technological research. If the intervention is successful and the system changes together with disappearance of the negative effects on the environment (externalities) we speak of a ‘systems innovation’.

Involved actors have different expectations and various implicit and explicit images of the targets and deal with different uncertainties. These perceptions have effect on the interactions. The co-ordination and communication activities of Innovative TA aim at the achievement of a common vision in the long run and common aims in the short run. This ‘reframing’ is necessary to arrive at a desired equilibrium development between technological possibilities and societal requirements.

7. Technology and innovation policy

Recently a shift occurred in the nature of the public support from technology push support towards demand pull program. It is assumed that this shift has greater acceptance of the crucial role of users in the recognition that technical success does not necessarily imply economic success. The European Commission’s Green Book on Innovation stresses the
urgent need for this shift. The EU (1996) observes the European technology paradox: a failure in Europe in translating excellence and strength in basic and fundamental research combined with failure to translate this in commercial excellence and success. As a result developing new products and new technology based firms failed.

The abovementioned finding is one of the arguments for government support for innovation projects. The advantages of co-operation between various groups (apart from business also including governments and societal groups) in clusters or networks, capturing problematic externalities also deserves support from the government. In the Netherlands clusters are a key element in innovation policy. Without such a support ‘the market’ will not solve these problems, Soete en Ter Weel (1999). The authors stress that the broad notion of knowledge accumulation (both embodied and disembodied technical change is challenging the traditionally segmented ‘market failure’ policy approach to science and technology support.

Also the theories of endogenous growth have implications for economic policy. According to Guellec and Ralle (1995) the state has to act on two ways: managing externalities created by the three factors of accumulation (physical, technological and human capital) and providing public goods.
<table>
<thead>
<tr>
<th>Aspect</th>
<th>Model</th>
<th>Techno-economic paradigm</th>
<th>Learning</th>
<th>Social shaping</th>
<th>Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aims at</td>
<td>Societal consequences</td>
<td>Influence of society</td>
<td>Synthesis</td>
<td>Integration</td>
<td></td>
</tr>
<tr>
<td>Type of action</td>
<td>Passive</td>
<td>Active</td>
<td>Interactive</td>
<td>Innovative</td>
<td></td>
</tr>
<tr>
<td>Technological development</td>
<td>Technology push</td>
<td>Endogenous</td>
<td>Demand pull</td>
<td>Co-evolution</td>
<td></td>
</tr>
<tr>
<td>Dynamics</td>
<td>Static</td>
<td>Comparative static</td>
<td>Dynamic</td>
<td>Evolutionary</td>
<td></td>
</tr>
<tr>
<td>Relationship with labour and organisation</td>
<td>Labour exit</td>
<td>HRM</td>
<td>Labour creation</td>
<td>Triad</td>
<td></td>
</tr>
<tr>
<td>Technology Assessment</td>
<td>TA</td>
<td>Constructive TA</td>
<td>Interactive TA</td>
<td>Innovative TA</td>
<td></td>
</tr>
<tr>
<td>Policy</td>
<td>Stimulating technological development</td>
<td>Market failure</td>
<td>Product innovation policy</td>
<td>Knowledge based</td>
<td></td>
</tr>
</tbody>
</table>
References


M.G. Christopher, 1992, Logistics and Supply Chain Management; Strategies for reducing costs and impoving services, London


EU (1996), The Green Book on Innovation, Brussels, EU


